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NONPROVISIONAL PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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BOX PATENT APPLICATION

NONPROVISIONAL APPLICATION TRANSMITTAL
RULE §1.53(b)

Director of the U.S. Patent and Trademark Office
Washington, D.C. 20231

Sir:

Transmitted herewith for filing under 37 C.F.R. §1.53(b) is the nonprovisional patent application

For (Title): DISPLAY DEVICES WITH INTEGRATED CONTROL ELEMENTS AND METHODS OF MAKING DEVICES

By (Inventors): Masanori IWAHASHI

- ☒ Formal drawings (Figs. 1-13B; 8 sheets) are attached.
☒ A Declaration and Power of Attorney is filed herewith.
☒ An assignment of the invention to Kawasaki Steel Corporation is filed herewith.
☒ An Information Disclosure Statement is filed herewith.
☐ Entitlement to small entity status is hereby asserted.
☐ A Preliminary Amendment is filed herewith.
☐ Please amend the specification by inserting before the first line the sentence --This nonprovisional application claims the benefit of U.S. Provisional Application No. _____, filed _____.--
☒ Priority of foreign application No. 11-341650 filed December 1, 1999 in Japan is claimed (35 U.S.C. §119).
☐ A certified copy of the above corresponding foreign application(s) is filed herewith.
☒ The filing fee is calculated below:

CLAIMS IN THE APPLICATION AFTER ENTRY OF
ANY PRELIMINARY AMENDMENT NOTED ABOVE

FOR:	NO. FILED	NO. EXTRA
BASIC FEE		
TOTAL CLAIMS	9 - 20	= 0
INDEP CLAIMS	4 - 3	= 1
<input type="checkbox"/> MULTIPLE DEPENDENT CLAIMS PRESENTED		

* If the difference is less than zero, enter "0".

SMALL ENTITY

RATE	FEE
	\$ 355
x 9 =	\$
x 40 =	\$
+ 135 =	\$
TOTAL	\$

OR
OR
OR
OR
OR
OR

OTHER THAN A
SMALL ENTITY

RATE	FEE
	\$ 710
x 18	\$
x 80	\$ 80
+ 270	\$
TOTAL	\$ 790

- ☒ Check No. 114013 in the amount of \$790 to cover the filing fee is attached. Except as otherwise noted herein, the Director is hereby authorized to charge any other fees that may be required to complete this filing, or to credit any overpayment, to Deposit Account No. 15-0461. Two duplicate copies of this sheet are attached.

Respectfully submitted,

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Prior Foreign Applications

Foreign Application One:: 11-341650
Filing Date:: December 1, 1999
Country:: Japan
Priority Claimed:: Yes
Foreign Application Two::
Filing Date::
Country::
Priority Claimed::
Foreign Application Three::
Filing Date::
Country::
Priority Claimed::

DISPLAY DEVICES WITH INTEGRATED CONTROL ELEMENTS AND METHODS OF MAKING DEVICES

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to display devices. This invention also relates to methods of making display devices.

2. Description of Related Art

Transmission-type, liquid-crystal display devices are currently the main stream of the liquid-crystal display devices. These devices require a back-light source on the back of the liquid crystal, the devices consume large amounts of power. In contrast, reflective-type, liquid-crystal display devices display an image by reflecting a light ray incident on the devices from an external light source, such as sunlight or room illumination, and thereby need no back-light source that consumes substantial power. Because of this feature, reflective-type, liquid-crystal displays operate on a substantially smaller power consumption level, and are thus expected to be incorporated in electronics used outdoors, such as portable telephones or portable information terminals.

In addition, reflective-type display devices have already found applications in projectors that use an external light source. A high-resolution feature is required for a display device that is incorporated in a projector. As the display device becomes high in resolution, the size of a unit pixel becomes small. For instance, a diagonally 0.9 inch VGA (video graphics array) display of 640 x 480 (307,200) pixels has a pixel size of about 28.6 μm . A SVGA (super video graphics array) display of 800 x 600 (480,000) pixels has a pixel size of 22.9 μm ; an XGA (extended graphics array) display of 1024 x 768 (786,432) pixels has a pixel size of 17.8 μm ; and a UXGA (ultra high extended graphics array) display of 1600 x 1200 (1,920,000) pixels has a pixel size of 11.4 μm .

Reflective-type, liquid-crystal display devices are constructed by successively stacking a transparent electrode, a liquid crystal, an array of pixel electrodes that reflect incident light from an external light source, and an array of control elements for controlling the alignment of the liquid crystal on the respective pixel electrodes. An example of the construction of reflective-type, liquid-crystal display device is described in U.S. Patent 6,049,132, which was co-invented by this inventor, hereby

Fig. 11 is a circuit diagram showing a portion of a conventional liquid-crystal display device including four rows by four columns of control elements. Each of the control elements 14 includes a switching circuit 28 including a PMOS transistor 24 and an NMOS transistor 26 connected in parallel. The pixel electrode, the liquid crystal, and the transparent electrode are connected between one terminal of the switching circuit 28 and the ground.

The gate of the PMOS transistor 24 and the gate of the NMOS transistor 26 are respectively connected to a pair of row drive lines 16 in each switching circuit 28 in the direction of the row, i.e., the horizontal direction in Fig. 11, in the control element 14. Each switching circuit 28 in the direction of the column, i.e., in the vertical direction, is configured with one terminal thereof connected to the respective pixel electrodes and the other terminal commonly connected to a column drive line 18.

Fig. 12 shows the layout of the display device of Fig. 11. Fig. 13A and Fig. 13B respectively show the layout and the circuit diagram of a single pixel. The shape of the unit pixel is typically square, although rectangular-shaped pixels with various aspect ratios may be utilized depending on the intended use. In any case, an aspect ratio of the pixel, or a ratio between the horizontal and vertical pitches of the pixel electrodes, may not be arbitrary determined, but is determined by the intended use. To configure the unit pixel in a square, or a fixed aspect ratio rectangular shape, the area of each control element should also be designed in the square shape, or in the fixed aspect ratio rectangular shape.

In many cases, a liquid-crystal display device requires higher operation voltage than the operation voltage of standard logic devices to drive a liquid crystal.

Therefore, it is difficult to miniaturize the control element beneath the layer of the pixel electrode. Further, the square, or the fixed aspect ratio rectangular shape, of the pixel adds to the difficulty of miniaturizing the pixel. That is, when a practically available transistor design rule is implemented, a layout with a minimum space may

Accordingly, it is an object of this invention to provide display devices, which overcome above-described disadvantages of known display devices.

10 Exemplary embodiments of the display devices according to this invention comprise: a semiconductor substrate; an array of control elements formed on the semiconductor substrate; and an array of reflective pixel electrodes arranged in rows and columns, the array of pixel electrodes is stacked over the array of control elements so that each of the control elements controls a state of reflection of a corresponding
15 one of the pixel electrodes. In the display devices, the control elements are arranged in a first direction that makes an angle greater than zero and smaller than a right angle with a direction of the rows, and in a second direction perpendicular to the first direction.

Preferably, embodiments of the display devices further comprise a converter. The converter receives a video signal including a series of image data in an order corresponding to the rows and columns of the pixel electrodes, and converts the order of the series of image data in the received video signal in accordance with correspondences between rows and columns of the array of control elements and the rows and columns of the pixel electrodes. Preferably, the array of control elements includes first drive lines extending in the first direction and second drive lines extending in the second direction.

7 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485 490 495 500 505 510 515 520 525 530 535 540 545 550 555 560 565 570 575 580 585 590 595 600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720 725 730 735 740 745 750 755 760 765 770 775 780 785 790 795 800 805 810 815 820 825 830 835 840 845 850 855 860 865 870 875 880 885 890 895 900 905 910 915 920 925 930 935 940 945 950 955 960 965 970 975 980 985 990 995 1000 1005 1010 1015 1020 1025 1030 1035 1040 1045 1050 1055 1060 1065 1070 1075 1080 1085 1090 1095 1100 1105 1110 1115 1120 1125 1130 1135 1140 1145 1150 1155 1160 1165 1170 1175 1180 1185 1190 1195 1200 1205 1210 1215 1220 1225 1230 1235 1240 1245 1250 1255 1260 1265 1270 1275 1280 1285 1290 1295 1300 1305 1310 1315 1320 1325 1330 1335 1340 1345 1350 1355 1360 1365 1370 1375 1380 1385 1390 1395 1400 1405 1410 1415 1420 1425 1430 1435 1440 1445 1450 1455 1460 1465 1470 1475 1480 1485 1490 1495 1500 1505 1510 1515 1520 1525 1530 1535 1540 1545 1550 1555 1560 1565 1570 1575 1580 1585 1590 1595 1600 1605 1610 1615 1620 1625 1630 1635 1640 1645 1650 1655 1660 1665 1670 1675 1680 1685 1690 1695 1700 1705 1710 1715 1720 1725 1730 1735 1740 1745 1750 1755 1760 1765 1770 1775 1780 1785 1790 1795 1800 1805 1810 1815 1820 1825 1830 1835 1840 1845 1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100 2105 2110 2115 2120 2125 2130 2135 2140 2145 2150 2155 2160 2165 2170 2175 2180 2185 2190 2195 2200 2205 2210 2215 2220 2225 2230 2235 2240 2245 2250 2255 2260 2265 2270 2275 2280 2285 2290 2295 2300 2305 2310 2315 2320 2325 2330 2335 2340 2345 2350 2355 2360 2365 2370 2375 2380 2385 2390 2395 2400 2405 2410 2415 2420 2425 2430 2435 2440 2445 2450 2455 2460 2465 2470 2475 2480 2485 2490 2495 2500 2505 2510 2515 2520 2525 2530 2535 2540 2545 2550 2555 2560 2565 2570 2575 2580 2585 2590 2595 2600 2605 2610 2615 2620 2625 2630 2635 2640 2645 2650 2655 2660 2665 2670 2675 2680 2685 2690 2695 2700 2705 2710 2715 2720 2725 2730 2735 2740 2745 2750 2755 2760 2765 2770 2775 2780 2785 2790 2795 2800 2805 2810 2815 2820 2825 2830 2835 2840 2845 2850 2855 2860 2865 2870 2875 2880 2885 2890 2895 2900 2905 2910 2915 2920 2925 2930 2935 2940 2945 2950 2955 2960 2965 2970 2975 2980 2985 2990 2995 3000 3005 3010 3015 3020 3025 3030 3035 3040 3045 3050 3055 3060 3065 3070 3075 3080 3085 3090 3095 3100 3105 3110 3115 3120 3125 3130 3135 3140 3145 3150 3155 3160 3165 3170 3175 3180 3185 3190 3195 3200 3205 3210 3215 3220 3225 3230 3235 3240 3245 3250 3255 3260 3265 3270 3275 3280 3285 3290 3295 3300 3305 3310 3315 3320 3325 3330 3335 3340 3345 3350 3355 3360 3365 3370 3375 3380 3385 3390 3395 3400 3405 3410 3415 3420 3425 3430 3435 3440 3445 3450 3455 3460 3465 3470 3475 3480 3485 3490 3495 3500 3505 3510 3515 3520 3525 3530 3535 3540 3545 3550 3555 3560 3565 3570 3575 3580 3585 3590 3595 3600 3605 3610 3615 3620 3625 3630 3635 3640 3645 3650 3655 3660 3665 3670 3675 3680 3685 3690 3695 3700 3705 3710 3715 3720 3725 3730 3735 3740 3745 3750 3755 3760 3765 3770 3775 3780 3785 3790 3795 3800 3805 3810 3815 3820 3825 3830 3835 3840 3845 3850 3855 3860 3865 3870 3875 3880 3885 3890 3895 3900 3905 3910 3915 3920 3925 3930 3935 3940 3945 3950 3955 3960 3965 3970 3975 3980 3985 3990 3995 4000 4005 4010 4015 4020 4025 4030 4035 4040 4045 4050 4055 4060 4065 4070 4075 4080 4085 4090 4095 4100 4105 4110 4115 4120 4125 4130 4135 4140 4145 4150 4155 4160 4165 4170 4175 4180 4185 4190 4195 4200 4205 4210 4215 4220 4225 4230 4235 4240 4245 4250 4255 4260 4265 4270 4275 4280 4285 4290 4295 4300 4305 4310 431

Other exemplary embodiments of the display devices according to this invention comprise: a semiconductor substrate; an array of control elements arranged in rows and columns formed on the semiconductor substrate; and an array of reflective pixel electrodes arranged in rows and columns with a first pitch and a second pitch.

5 The array of pixel electrodes is stacked over the array of control elements so that each of the control elements controls a state of reflection of a corresponding one of the pixel electrodes. The control elements are arranged in same directions of the rows and columns of the pixel electrodes with a third pitch different from the first pitch, a fourth pitch different from the second pitch, and a product of the first and the second
10 pitches equal to a product of the third and the fourth pitches.

Preferably, the state of reflection is controlled by one of (i) controlling an alignment of a liquid-crystal layer disposed over the corresponding one of the pixel electrodes, and (ii) controlling an angle of the corresponding one of the pixel electrodes.

15 This invention also provides embodiments of methods of forming the display devices.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates an embodiment of a display device according to this invention;

20 Fig. 2 illustrates the positional relationship between a pixel electrode and a control element in a single pixel in the display device of Fig. 1;

Fig. 3 is a layout view of the display device of Fig. 1;

Fig. 4 is a layout view showing the positional relationship between a pixel electrode and a control element in a single pixel in the display device of Fig. 3;

25 Fig. 5 shows a wiring configuration of a display device according to this invention;

Fig. 6 is a layout view showing a wiring configuration of the display device of Fig. 5;

30 Fig. 7 is a layout view showing the wiring configuration and the positional relationship between the a pixel electrode and a control element in the display device of Fig. 6;

Fig. 8 shows the positional relationship between pixel electrodes and control elements in two pixels in the display device in an embodiment of the invention;

Figs. 9A and 9B show the configuration of the control elements used in the display device of the invention;

Figs. 10A-10C show the configuration of the pixel electrodes used in the display device in one embodiment of the invention;

Fig. 11 is a circuit diagram showing the construction of a conventional display device;

Fig. 12 is a layout view of the display device of Fig. 11; and

Figs. 13A and 13B show a layout view and a circuit diagram, respectively, of a single pixel of the display device of Fig. 11.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

This invention was first disclosed in Japanese Patent Application No. 11-341650, which is hereby incorporated by reference in its entirety.

Preferred embodiments of the display devices of this invention are discussed below with reference to the drawings.

Fig. 1 is a conceptual view of an exemplary embodiment of the display devices of this invention. Fig. 2 is a conceptual view showing the positional relationship between a pixel electrode and a control element in a single pixel in the display device of Fig. 1. In these views, squares and rectangles represent pixel electrodes and control elements, respectively. The squares and rectangles shown in Figs. 1 and 2 represent areas to form the pixel electrode and the control element, and the pixel electrode and the control element may actually have various structures formed within respective areas.

Referring to Fig. 1, a display device 10 of this invention includes, on a semiconductor substrate (not shown), an array of a plurality of reflective-type pixel electrodes 12 for reflecting incident light, and an array of a plurality of control elements 14, stacked correspondingly below the plurality of the pixel electrodes 12, for controlling the state of reflection of light from the plurality of the pixel electrodes 12.

In this embodiment, each pixel electrode 12 is formed in a square region. That is, the pixel electrodes 12 are arranged with the same pitch in the direction of rows (i.e., in the horizontal direction in Fig. 1) and in the direction of columns (i.e., in the vertical direction in Fig. 1). The control elements 14 are arranged with different pitches, one pitch in a first direction angled at 45° to the direction of rows, and with

the other pitch in a second direction perpendicular to the first direction. Row drive lines and column drive lines are respectively arranged in the first direction and the second direction. Although each two row drive lines 16 may be paired together as shown in Fig. 11, only a single row drive line is shown in Fig. 1 for each row of the control elements 14 for simplicity.

Referring to Fig. 2, the pixel electrode 12 is formed in a square region having an aspect ratio of 1:1, while the control element 14 is formed in a rectangular region having an aspect ratio of 2:1. The areas of the two regions are equal to each other. In this embodiment, the aspect ratio of the area for forming the control element 14 is 2:1, and the area is angled at 45° to the pixel electrodes 12. Depending on the aspect ratio of the control element 14, the inclination angle of the control element 14 to the pixel electrode 12 may be selected to be any angle within a range greater than zero and smaller than a right angle (i.e., 90°).

Fig. 3 is a layout view of the display device of Fig. 1. Fig. 4 is a layout view showing the positional relationship between a pixel electrode and a control element in a single pixel in the display device of Fig. 3. In these layout views, structures of the pixel electrode and the control element formed within the areas 12 and 14 shown in the views of Figs. 1 and 2 are shown. As shown, nine control elements 14 are respectively arranged for an array of 3 x 3 pixel electrodes 12. The row drive lines 16 and the column drive lines 18 are respectively arranged in the first direction and in the second direction. That is, in this embodiment, the row drive lines 16 extend in the direction of rows of the array of control elements 14, which is inclined from the direction of rows of the array of pixel electrodes 12. Similarly, the column drive lines 18 extend in the direction of columns of the array of control elements 14, which is inclined from the direction of columns of the array of pixel electrodes 12.

Referring to Fig. 4, the rectangular region 14 forming the control element is separated in two square regions by a center line represented by the broken line A. The lower-left one of these square regions 14' is a P-well region, and an NMOS transistor 26 is formed in a central, rectangular area in the lower-left square region. The upper-right square region 14" is an N-well region, and a PMOS transistor 24 is formed in a central, rectangular area in the upper-right square region. Lines 16' diagonally extending from the upper left to the lower right respectively serve as gates of the transistors. The gates of the plurality of control elements are connected and form the

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in the first and second direction, respectively, at an angle with the directions of rows and columns.

This invention is not limited to this arrangement. The pixel electrodes 12 may alternatively be arranged in an array with the same pitch in the direction of rows and in the direction of columns, while the control elements 14 are arranged in an array with different pitches, one pitch in the direction of rows, and with the other pitch in the direction of columns.

Fig. 8 is a conceptual view showing the positional relationship between pixel electrodes 12 and control elements 14 in two pixels in another exemplary embodiment of the display devices of this invention. As shown, two rows of pixel electrodes 12 are arranged correspondingly to a single row of the control elements 14. The pixel electrodes 12 have an aspect ratio of 1:1 and are arranged in an array with the same pitch in the directions of rows and columns. The control elements 14 of this embodiment are not inclined to the pixel electrodes 12, but have an aspect ratio different from that of the pixel electrode 12. That is, the control elements 14 have an aspect ratio of 4:1 and are arranged in an array with different pitches, one pitch in the direction of rows and the other pitch in the direction of columns.

The area of the square region 12 to form the pixel electrode is equal to the area of the rectangular region 14 to form the control element, and the pixel electrodes 12 partly overlap the corresponding control elements 14. In other words, the square of the arrangement pitch of the pixel electrodes 12 is equal to the product of the arrangement pitches of the control elements 14 in the directions of the rows and the columns. If the region to form the pixel electrode 12 has a rectangular shape, the product of the arrangement pitches of the pixel electrodes 12 in the directions of rows and columns is equal to the product of the arrangement pitches of the control elements 14 in the directions of rows and columns.

A combination of the two pixel electrodes 12 and the two control elements 14 shown in Fig. 8 is treated as a unit. Such units are periodically arranged in an array to construct the display device of this invention. As shown, the aspect ratio of the control element 14 is 4:1, and the pixel electrodes 12 and the control elements 14 combined in a two-to-two correspondence are periodically arranged.

However, this invention is not limited to only this arrangement. Rather, depending on the aspect ratio of the control element 14, any suitable plural-to-plural correspondence between the pixel electrodes and the control elements can be adopted.

In this invention, the shape of the area to form the pixel electrode 12 is not limited to a square, and the shape of the area to form the control element 14 is not limited to a rectangular shape. Referring to Figs. 9A-10C, variations of configurations of the pixel electrodes 12 and the control elements 14 are shown. In Figs. 9A and 9B, solid lines represent areas to form control elements 14. In Figs. 10A-10C, solid lines represent areas to form pixel electrodes 12.

The array of the control elements 14 includes any array, which may be regarded as an array of substantially rectangular shapes, even if the area to form the control element is not completely rectangular. Referring to Figs. 9A and 9B, the areas surrounded by solid lines are variations of the rectangular-shaped unit cell areas represented by broken lines. Arrangements of control elements 14 shown in Figs. 9A and 9B fall within the scope of this invention. There is no particular limitation on the shape of the control element 14. For example, a combination of triangles or pentagons may be periodically repeated.

Also, arrangements of pixel electrodes shown in Figs. 10A-10C all fall within the scope of this invention. Shapes of the areas to form pixel electrodes represented by solid lines are mere variations of squares represented by broken lines.

The conventional switching circuit shown in Fig. 11 may be employed as the circuit arrangement of the control element in embodiments of this invention. The layout configuration of the control element 14 is not limited to any particular configuration and may be freely modified. In addition to the switching circuit, the control elements 14 may also include a capacitor.

As discussed above, in the display devices of this invention, an array of control elements is arranged to correspond to an array of pixel electrodes arranged in an upper layer even when miniaturization of the control elements does not permit the shape of the control elements in a lower layer to match the shape of the pixel electrodes. This invention thus provides a compact and high-resolution reflective-type display device, which is thus easy to design, and is appropriate for use in projectors and various other devices.

This invention is not limited to the above-described embodiments, and various changes and modifications may be incorporated in this invention without departing from the scope of this invention.

WHAT IS CLAIMED IS:

1. A display device, comprising:
a semiconductor substrate;
an array of control elements on the semiconductor substrate; and
5 an array of reflective pixel electrodes arranged in rows and columns,
the array of pixel electrodes is stacked over the array of control elements so that each
of the control elements controls a state of reflection of a corresponding one of the
pixel electrodes,
wherein the control elements are arranged (i) in a first direction that
10 makes an angle greater than zero and smaller than 90° with a direction of the rows,
and (ii) in a second direction perpendicular to the first direction.
2. The display device according to claim 1, wherein the state of reflection
is controlled by one of (i) controlling alignment of a liquid-crystal layer disposed over
the corresponding one of the pixel electrodes, and (ii) controlling an angle of the
15 corresponding one of the pixel electrodes.
3. The display device according to claim 1, further comprising a converter
that (i) receives a video signal including a series of image data in an order
corresponding to the rows and columns of the pixel electrodes, and (ii) converts the
order of the series of image data in the received video signal in accordance with
20 correspondences between rows and columns of the array of control elements and the
rows and columns of the pixel electrodes.
4. The display device according to claim 3, wherein the array of control
elements includes first drive lines extending in the first direction and second drive
lines extending in the second direction.
- 25 5. The display device according to claim 1, wherein the array of control
elements includes row drive lines extending in a direction of the rows of the array of
the pixel electrodes, and column drive lines extending in a direction of the columns of
the array of the pixel electrodes.
6. A display device, comprising:
30 a semiconductor substrate;
an array of control elements arranged in rows and columns formed on
the semiconductor substrate; and
an array of reflective pixel electrodes arranged in rows and columns
with a first pitch and a second pitch, the array of pixel electrodes is stacked over the

array of control elements so that each of the control elements controls a state of reflection of a corresponding one of the pixel electrodes:

5 wherein the control elements are arranged in same directions as the rows and columns of the pixel electrodes with (i) a third pitch different from the first pitch, (ii) a fourth pitch different from the second pitch, and (iii) a product of the first and the second pitches equal to a product of the third and the fourth pitches.

7. The display device according to claim 6, wherein the state of reflection is controlled by (i) one of controlling an alignment of a liquid-crystal layer disposed over the corresponding one of the pixel electrodes, and (ii) controlling an angle of the corresponding one of the pixel electrodes.

8. A method of making a display device, comprising:
forming an array of control elements on the semiconductor substrate;
and
forming an array of reflective pixel electrodes arranged in rows and
15 columns, the array of pixel electrodes being stacked over the array of control elements so that each of the control elements controls a state of reflection of a corresponding one of the pixel electrodes,

20 wherein the control elements are arranged (i) in a first direction that makes an angle greater than zero and smaller than 90° with a direction of the rows, and (ii) in a second direction perpendicular to the first direction.

9. A method of making a display device, comprising:
forming an array of control elements arranged in rows and columns on a semiconductor substrate; and
forming an array of reflective pixel electrodes arranged in rows and
25 columns with a first pitch and a second pitch, the array of pixel electrodes being stacked over the array of control elements so that each of the control elements controls a state of reflection of a corresponding one of the pixel electrodes:

30 wherein the control elements are arranged in same directions as the rows and columns of the pixel electrodes with (i) a third pitch different from the first pitch, (ii) a fourth pitch different from the second pitch, and (iii) a product of the first and the second pitches equal to a product of the third and the fourth pitches.

ABSTRACT OF THE DISCLOSURE

A display device includes an array of control elements formed on a semiconductor substrate, and an array of reflective-type pixel electrodes stacked over the array of the control elements, so that each of the control elements control a state of reflection of a corresponding one of the pixel electrodes. The array of the pixel electrodes is arranged in rows and columns. In embodiments, the array of the control elements is arranged in a first direction that makes an angle greater than zero and smaller than 90° with the direction of rows, and in a second direction that is perpendicular to the first direction. The display device has an array of control elements corresponding to the array of pixel electrodes even when the control elements do not match the pixel electrodes in shape. This invention also provides methods of making the display devices.

FIG. 1

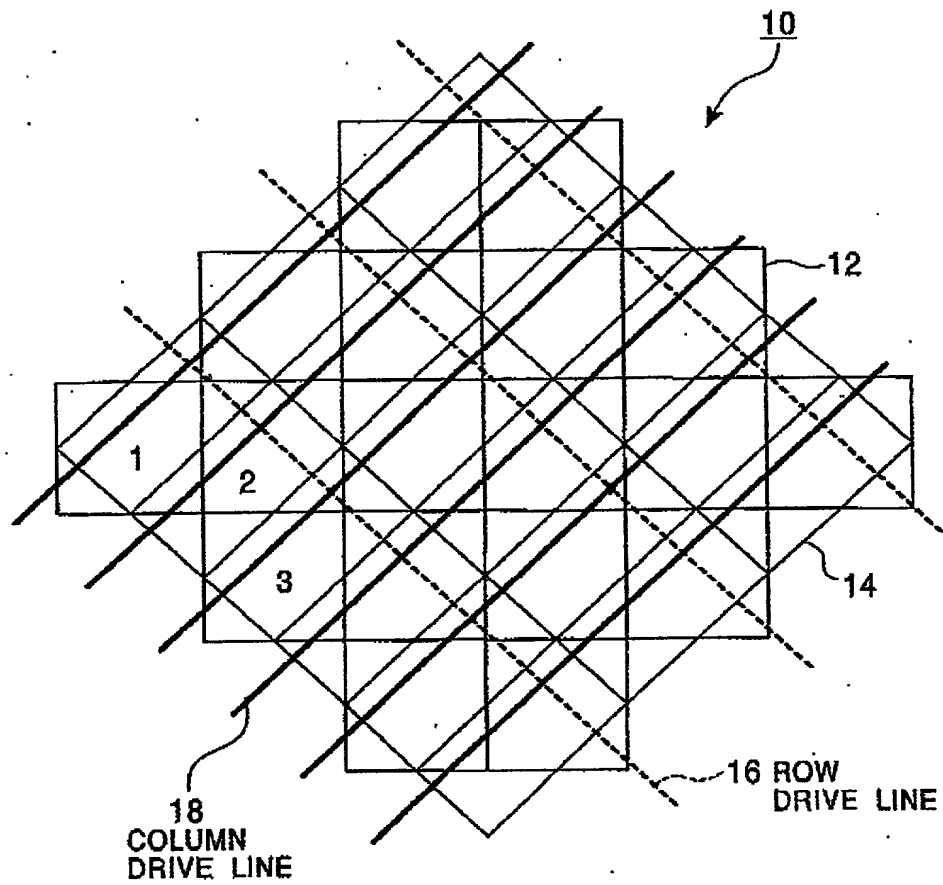


FIG. 2

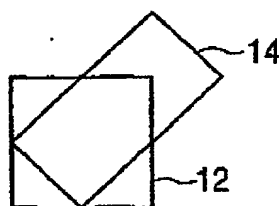


FIG. 3

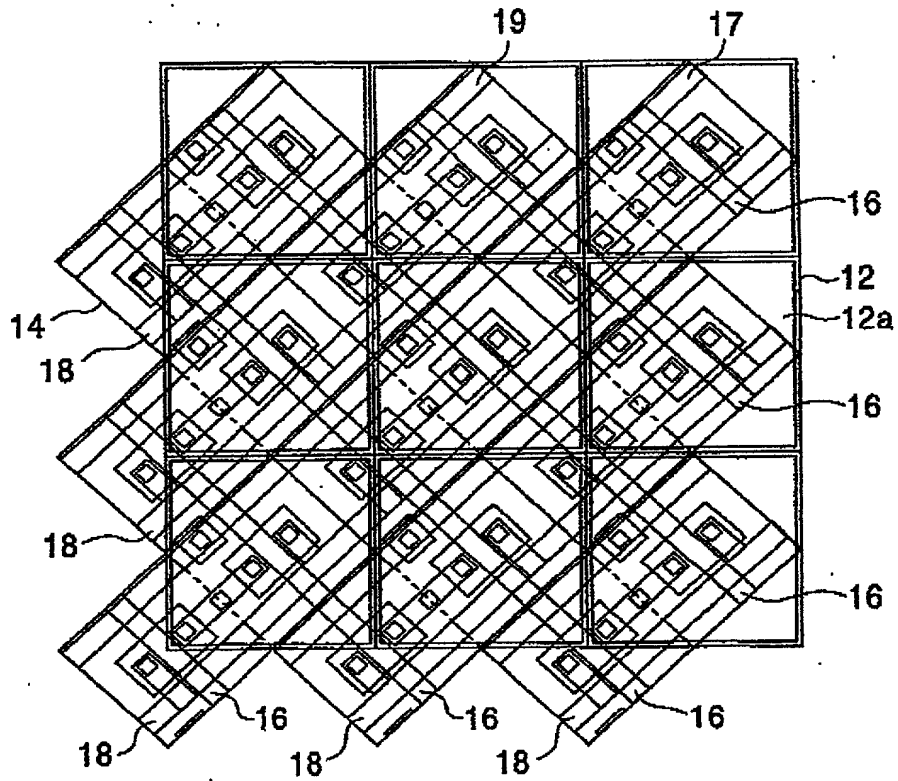


FIG. 4

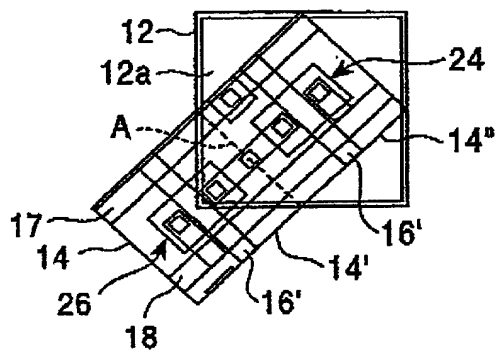


FIG. 5

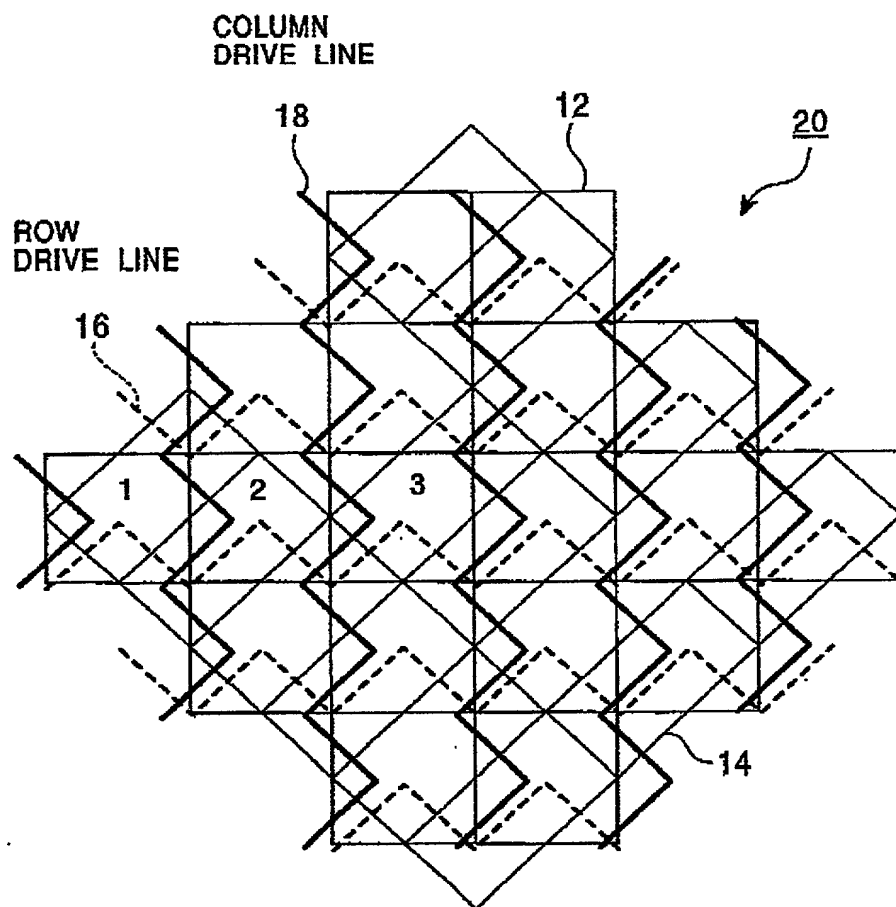


FIG. 6

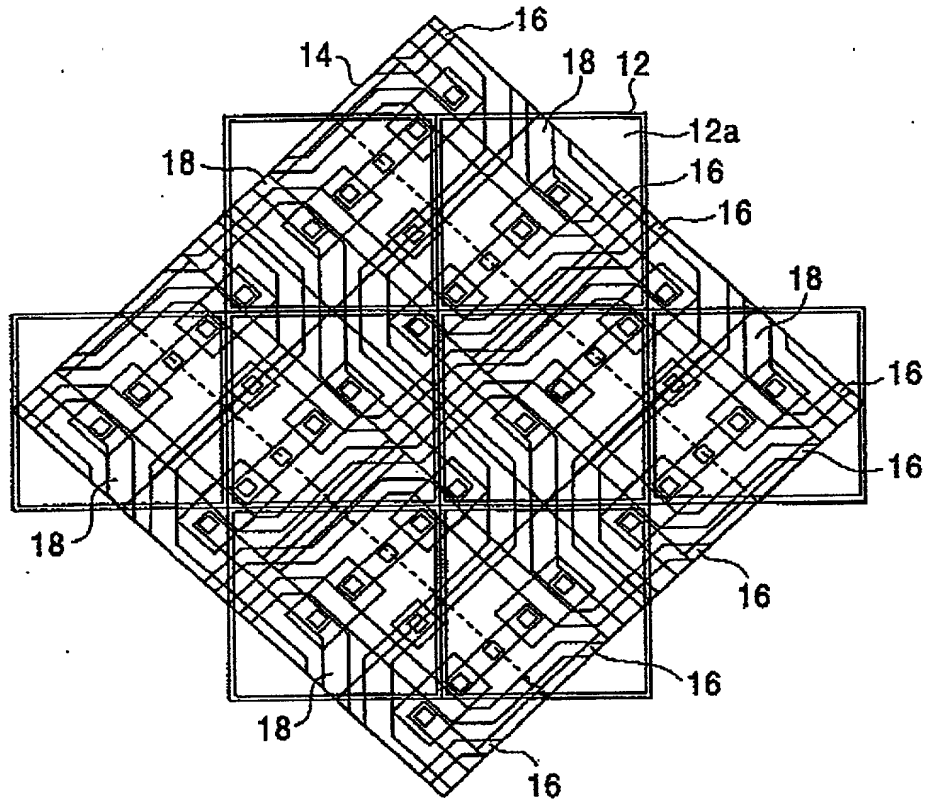


FIG. 7

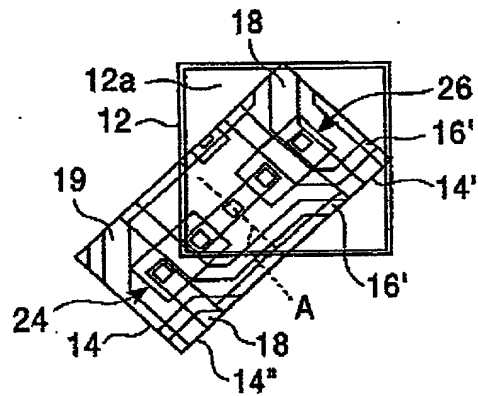


FIG. 8

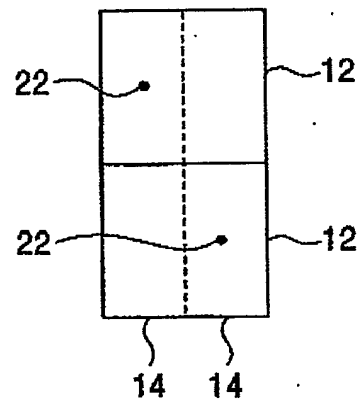


FIG. 9A

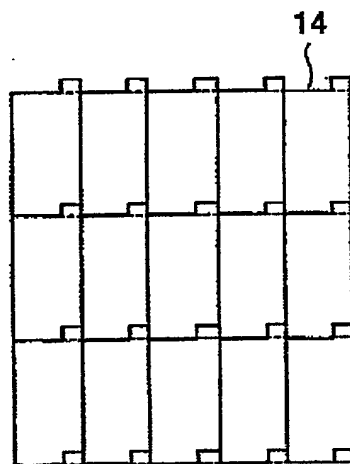


FIG. 9B

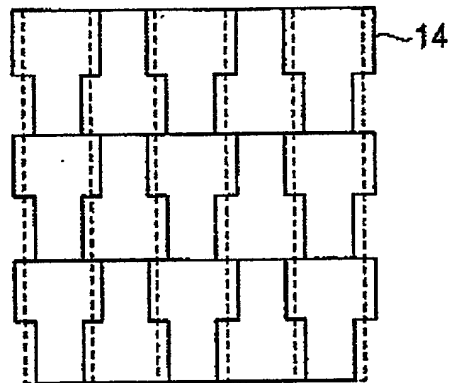


FIG. 10A

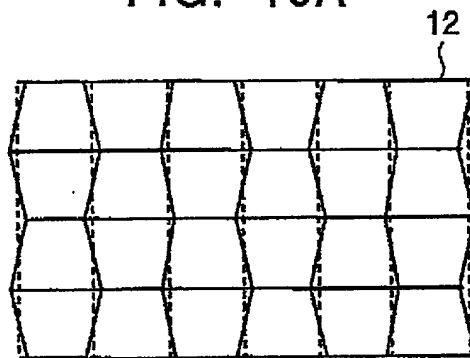


FIG. 10B

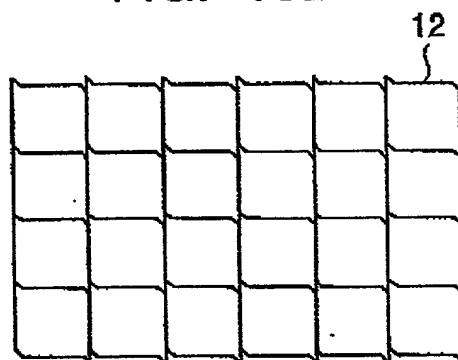


FIG. 10C

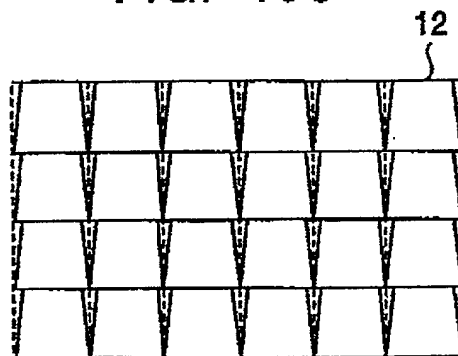


FIG. 11

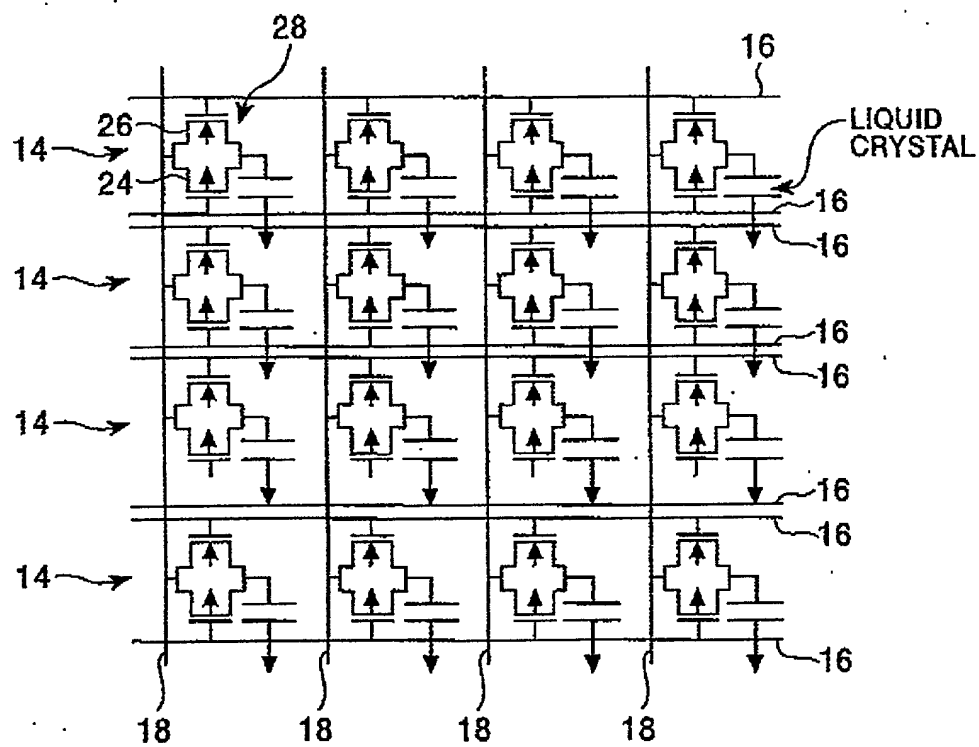


FIG. 12

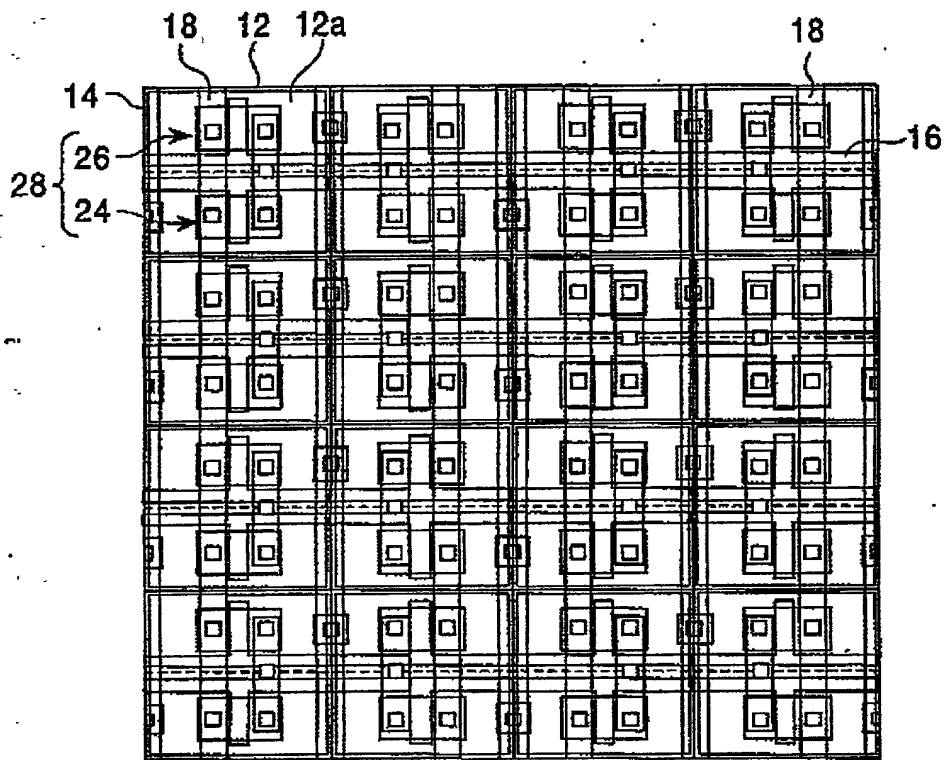


FIG. 13A

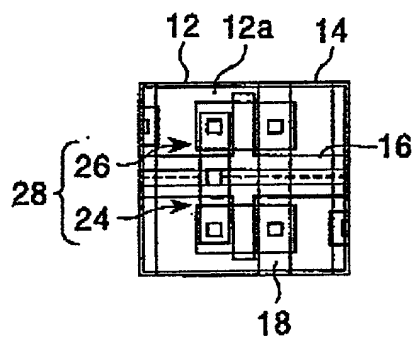
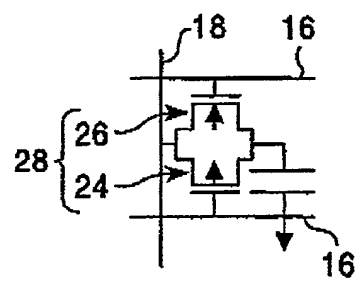


FIG. 13B



Declaration and Power of Attorney for Patent Application

特許出願宣言書兼委任状

Japanese Language Declaration

私は、下欄に氏名を記載した発明者として、以下のとおり宣言する：

私の住所、郵便先および国籍は、下欄に氏名に続いて記載したとおりであり、下記名称の発明に關し、特許請求の範囲に記載した特許を求める主題の本来の、最初にして唯一の発明者である（一人の氏名のみが下欄に記載されている場合）か、もしくは本来の、最初にして共同の発明者である（複数の氏名が下欄に記載されている場合）と信じ、

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name. I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

DISPLAY DEVICES WITH INTEGRATED CONTROL ELEMENTS

AND METHODS OF MAKING DEVICES

その明細書を
(添付するものにチェック)

☒ここに添付する。

☐ 年 月 日に

出願番号第 として提出され、

年 月 日に補正し、
(添付する場合)

私は、前記のとおり補正した特許請求の範囲を含む前記明細書の内容を検討し、理解したことを確述する。

私は、連邦施行規則第 37 章第 1 条第 56 項に従い、本願の特許性の有無について重要な情報を開示すべき義務を有することを認める。

私は、米国法第 35 章第 119 条に基づく下記の外国特許出願もしくは発明者証出願の外国優先権利益を主張し、さらに優先権の主張に係わる基礎出願の提出日前の提出日を有する外国特許出願もしくは発明者証出願および/もしくは米国仮出願を以下に明記する：

the specification of which
(check one)

☒ is attached hereto.

☐ was filed on 88

Application Serial No. _____

and was amended on _____
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code §119 of any foreign application(s) for patent or inventor's certificate listed below and/or any U.S. provisional application(s) listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior foreign and/or provisional applications
先行外国出願/仮出願

Priority claimed
優先権の主張

11-341650 (Number/番号)	Japan (Country/国名)	1 December 1999 (Day/Month/Year Filed/提出年月日)	<input checked="" type="checkbox"/> (Yes/はい)	<input type="checkbox"/> (No/いいえ)
_____ (Number/番号)	_____ (Country/国名)	_____ (Day/Month/Year Filed/提出年月日)	<input type="checkbox"/> (Yes/はい)	<input type="checkbox"/> (No/いいえ)
_____ (Number/番号)	_____ (Country/国名)	_____ (Day/Month/Year Filed/提出年月日)	<input type="checkbox"/> (Yes/はい)	<input type="checkbox"/> (No/いいえ)
_____ (Number/番号)	_____ (Country/国名)	_____ (Day/Month/Year Filed/提出年月日)	<input type="checkbox"/> (Yes/はい)	<input type="checkbox"/> (No/いいえ)

私は、米国法第 35 章第 120 条に基づく下記の米国特許出願の利益を主張し、本願の特許請求の範囲各項に記載の主題が米国法第 35 章第 112 条の第 1 段落に規定の態様で先の米国出願に開示されていない限度において、先の出願の提出日と本願の国内提出日もしくは PCT 国際出願提出日の間に公表された連邦施行規則第 37 章第 1 条第 56 項に記載の重要な情報を開示すべき義務を有することを認める。

I hereby claim the benefit under Title 35, United States code, §120 of any United States application(s) listed below and, in so far as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112. I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

_____ (Application Serial No./出願番号)	_____ (Filing Date/提出日)	_____ (Status: Patented, Pending, abandoned/ 現状: 特許成立、係属中、放棄済み)
_____ (Application Serial No./出願番号)	_____ (Filing Date/提出日)	_____ (Status: Patented, Pending, abandoned/ 現状: 特許成立、係属中、放棄済み)

私は、ここに自己の知識にもとづいて行った陳述がすべて真実であり、自己の有する情報および信ずるところに従って行った陳述が真実であると信じ、さらに故意に虚偽の陳述等を行った場合、米国法第 18 章第 1001 条により、罰金もしくは禁錮に処せられるか、またはこれらの刑が併科され、またかかる故意による虚偽の陳述が本願ないし本願に対して付与される特許の有効性を損なうことがあることを認識して、以上の陳述を行ったことを宣言する。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

委任状：私は下記発明者として、以下の代理人をここに委任し、本願の手続きを遂行すること並びにこれに關する一切の行為を特許商標庁に対して行うことを委任する。(代理人氏名および登録番号を明記のこと)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

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Full name of sole or first inventor/専横または第一発明者の氏名 Masanori IWAHASHI	
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Residence/住所	
Citizenship/国籍 Japan	
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Full name of second joint inventor (if any)/第二共同発明者の氏名(該当する場合)	
Second inventor's signature/第二発明者の署名	Date/日付
Residence/住所	
Citizenship/国籍	
Post Office Address/郵便先	

Supply similar information and signature for third and subsequent joint inventors.
第三又はそれ以後の共同発明者に対して同様の情報および署名を供給すること。